

SUBJECT: Apollo Communications - Operational
Constraints During Lunar Surface
Activities - Case 320

DATE: March 28, 1969

FROM: W. H. Hodge

MEMORANDUM FOR FILE

INTRODUCTION

This memorandum reviews the operational use of the Apollo communications during lunar surface activities. The discussion here is directed primarily at the G Mission, but it should stimulate thought concerning future lunar landing missions. A simplified functional description is provided to aid this thought about future missions and also to serve as a basis for discussion of operational considerations regarding the first lunar landing. Many varied factors such as antenna visibility, metabolic loading uncertainties, consumables budgeting, and live TV coverage constrain the use of the communication systems during lunar surface activities. This discussion of these constraints points out potential problems and suggests courses of action to alleviate the problems.

I. FUNCTIONAL DESCRIPTION OF THE COMMUNICATION SYSTEMS

The LM Communications System consists of VHF (250-300 MHz in this case) and S-band (2100-2200 MHz) subsystems, LM instrumentation data circuitry, crew audio and biomedical circuitry, and the necessary signal processing equipment as shown in Figure 1.

The VHF sub-system is used for communications with the Command Module and the extravehicular crewmen. It consists of two transmitters, two receivers, and three antennas (Figure 2). Only one of the two receivers can receive biomedical and suit data from an extravehicular crewman; they can both receive voice. When communicating with the CM, one of the two inflight antennas is used -- aft or forward depending on the LM attitude with respect to the CM. When communicating with crewmen on the surface, the EVA antenna provides omnidirectional coverage around the LM. Only one of the three antennas can be used at a time - the selection is made by manual switch operation in the LM cabin.

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The S-band subsystem which provides the deep space link between the LM and the MSFN, has the capability for transmission of voice, biomed data, TV, and systems data. Most of the time this link uses the steerable antenna on the top of the ascent stage. However, two other S-band antennas provide additional coverage. The capability exists to employ a high-gain dish antenna that can be erected on the lunar surface during extravehicular activity. This added gain could alleviate a high data transmission rate problem discussed in detail below.

The intravehicular crewmen are linked to the LM Communications System by electrical umbilicals. Voice signals are sent to and from the crewmen, and biomedical data are sent from the crewmen. The biomedical data -- which consists of a heart beat signal (EKG - Electrocardiogram) and respiration rate -- can only be sent from one crewman at a time. Selection of which crewman's biomed data will be transmitted is made by manual operation of a switch on the LM panel.

LM systems instrumentation data is sent over the S-band link to the MSFN. Data flow can occur at a high or low rate; selection is made manually by a panel switch.

When the two LM crewmen don their Portable Life Support Systems, they begin to use the Extravehicular Communication Systems (EVCS) which together with the extravehicular suit and the PLSS make up the Extravehicular Mobility Unit (EMU). Communications between the EVCS and the LM/MSFN use VHF links and the EVA antenna to obtain coverage in all directions around the LM (Figure 3). The extravehicular crewmen have a full duplex communications link with the LM/MSFN. That is, all three elements can send and receive at the same time. The crewmen transmit signals consisting of voice, biomed data, and EMU systems data and receive voice signals from the LM/MSFN. The EMU systems data is shown in Table 1. The only biomed measurement telemetered over the EVCS is heart beat (EKG); the respiration rate measurement available when the crewmen are connected to the LM Communication System by umbilical is not available when the EVCS is used. However, while biomed data can be obtained from only one crewman at a time when they are hard-wired to the LM, the EKG measurement from both crewmen can be obtained simultaneously when both are using their EVCS.

Each EVCS contains an assortment of transmitters and receivers (Figure 4). Various combinations of this equipment can be manually selected by operation of a mode select switch on the EMU Remote Control Unit -- a small control box mounted on the crewman's chest. Three modes are available on each EVCS (Table 2). The nominal mode for operating the two EVCS's

simultaneously is illustrated in Figure 4. In this configuration, the crewman wearing EVCS-1 (probably the first man to egress) serves as a relay for communication from the other crewman to the LM/MSFN. A full duplex voice net is established between the crewmen and the LM/MSFN, and the LM/MSFN is, in addition, receiving EMU systems data and EKG signals from both crewmen.

II. OPERATIONAL CONSIDERATIONS

Present plans for lunar surface EVA on the first lunar landing mission call for two crewmen to be on the surface at the same time. One of the two, however, will precede the other to the surface for a short period (about 50 minutes) while he performs initial checks and collects the contingency sample. The other crewman will then join him on the surface for the remainder of the EVA period. For two reasons, both crewmen don their PLSS's before depressurizing the LM for the EVA. First, it is doubtful that one man can don his PLSS without assistance from the other. Second, if the crewman who stays in the LM were to wait until after egress by the first to perform the switch-over from LM systems to EMU systems, he would have to perform either a vacuum disconnect from the LM systems or go through a second repress/depress cycle of the LM. Vacuum disconnection of life support umbilicals is considered hazardous. Requiring a second depress/repress cycle has an obvious consumables penalty. In addition, it would not be wise from a safety standpoint to close and seal the LM hatch and pressurize the LM with a man on the surface. Thus, the two-man EVA creates a situation involving two men in EMU's - one on the lunar surface and one inside the LM.

A. Line-Of-Sight Considerations

This one-in/one-out situation could present a line-of-sight communications problem. The propagation of VHF radiation roughly follows a visual line-of-sight. This raises the question of whether two crewmen must maintain a strict line-of-sight contact to preserve their communications link. Tests have recently been completed at MSC to determine the extent of this line-of-sight limitation on the use of the EVCS's when one man is in the LM and the other is outside the LM. The tests involved use of LTA-8 and prototype EVCS's in an anechoic chamber. Voice communications were never lost regardless of the relative positions of the two crewmen. However, a few short duration telemetry drop-outs did occur. The test personnel were reluctant to attribute the drop-out to a line-of-sight problem; they suspected a faulty LM communications

system. As a hedge against the possibility of TM drop-outs, however, the MSC personnel in charge of the EVCS recommend that the first man to egress the LM carry the EVCS which serves as a relay for the other. This recommendation is based on the idea that a TM loss from the intravehicular crewman could be tolerated more readily than a TM loss from the man on the surface.

B. Bandwidth/Power Limitation

Present G Mission plans call for the first crewman out of the LM to pause at the top of the LM ladder and open the Modularized Equipment Stowage Assembly (MESA), which is located in the side of the descent stage adjacent to the ladder. A TV camera will have been mounted inside the MESA in such a position that when the MESA is opened, the camera will be covering the foot of the ladder and surrounding lunar surface area. This camera will be turned on by the intravehicular crewman to begin a live telecast to earth of man's first steps onto the lunar surface. This operation necessarily precedes deployment of the erectable antenna on the lunar surface.

Because this one-time requirement for using TV before the high-gain surface antenna has been erected was not known at the time of the LM Communication System was designed, the telecast presents a possible bandwidth/power problem. Analysis has shown that simultaneously transmitting a TV signal with voice, EMU data, and EKG data from two crewman may result in degraded EMU and EKG signals unless either the LM erectable antenna or a 210 foot earth-based antenna can be used.* (The circuit margins when using the 85 foot MSFN antennas and the LM steerable antenna are too low to assure reliable transmission of these data.) While, it is not certain that a data loss would actually occur during an initial G Mission telecast, the possibility must be recognized in mission planning. During later missions, live telecasts can wait for erection of the surface antenna.

It is much too late in the program to redesign the hardware, especially to accommodate a one-time requirement

*N. W. Schroeder, Power Margins for the LM/MSFN (85') Communications Link at Lunar Range, Bellcomm Memorandum for File, September 23, 1968.

such as an initial lunar telecast. The focus, then, is on what can be done operationally to cope with the potential problem.

OPTIONS

1. ELIMINATION OF LIVE TV FOR FIRST STEPS ON LUNAR SURFACE

The desirability of a live telecast of man's first steps on the lunar surface involves considerations that are beyond the scope of this memorandum. Planning for this telecast is well into the hardware implementation stage.

2. REMAINING ON LM SYSTEMS DURING INITIAL TELECAST

Since the circuit margin problem does not exist when only one man is using his EVCS, one possibility would involve postponing the intravehicular crewman's switch-over from LM communications and life-support systems to EMU systems until after the extravehicular crewman has erected the dish antenna on the surface. But as discussed above in connection with the line-of-sight problem this alternative creates problems of its own -- i.e., repress/depress or vacuum disconnect. This latter dilemma could conceivably be avoided, however, by only postponing switch-over of the electrical/communications umbilical was still providing communications. This too has its shortcomings. The LM umbilical does not contain circuits for telemetering EMU systems data. The crewman would therefore be using his EMU for life support while mission control had no idea what its status was. The crewman himself has some status information available, but the wisdom of requiring him to perform his activities while monitoring his EMU is questionable.

3. DOING WITHOUT EMU AND EKG DATA

This leads to the PLSS/metabolic loading uncertainties factor. What will be required of the PLSS during lunar surface activities is not firmly established. Nor is its capability in that situation known with certainty. The determination of PLSS limitations therefore requires as much real-time information as possible. Among the factors which contribute to a lack of certainty in this area are the effect of a 1/6G gravitational field, lunar surface traction variations, the lack of operational experience with the PLSS, psychological factors of excitement and anxiety, and the inherent variations from crewman to crewman. Adding all these factors together creates a picture of uncertainty about what the PLSS will be asked to do and how well it can do whatever is required during lunar surface activity.

For this reason, it is important to maintain a thorough and continuous check on the biomed and EMU systems data while the EMU is in use. It is important not only in order to better understand the combined effects of all these factors, but also to determine when the PLSS consumables red lines are being approached. Thus, living with losses of EMU and EKG data, even for short periods, has its drawbacks.

4. PLANNING FOR HIGH GAIN ANTENNA VISIBILITY

Another alternative to alleviate the problem would involve planning the initiation of EVA to coincide with visibility of a 210 foot earth-based antenna. The 210 foot Goldstone dish is the only such antenna now actually ready for use. The 210 foot dish at Parkes, Australia, however, is currently being readied for use during the first lunar landing mission. Studies of the availability of 210 foot coverage during lunar surface activity have been performed.* It has been concluded that for the present G Mission, free return profile, a 210 foot station in Australia as well as in Goldstone is needed to provide a high probability of covering the first lunar EVA for launches during the latter half of 1969. Even with the Australian antenna available, however, mission planning would be somewhat constrained to begin the EVA while a 210 foot dish was visible. In light of the other factors mentioned above, however, this may present the least of several inconveniences.

CONCLUSIONS

At least two potential operational communications problems are presented by the first lunar landing plans -- a line-of-sight constraint and a bandwidth/power limitation. The line-of-sight limitation, however, does not appear to be serious, if existent at all. The MSC recommendation that the relay EVCS be carried by the first man to egress the LM is a sound one. If a telemetry loss were to occur as a result of some problem with the relay link, it would be desirable to have the crewman from whom no telemetry is being received in as conservative a situation as possible.

Possible operational solutions to the potential bandwidth/power problem include elimination of the telecast of man's first steps on the lunar surface, leaving the intravehicular crewman on LM systems during the telecast, doing without EMU and EKG data from the intravehicular crewman during the telecast, and planning for high-gain earth based antenna visibility during the telecast. Of these alternatives, planning for use of a 210

*D. R. Anselmo, Lunar Surface Television Coverage from Parkes, Australia, Bellcomm Memorandum for File, February 5, 1969.

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foot earth-based antenna seems to be the least undesirable solution to the potential problem presented by TV plans for the first landing mission.

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Attachments

Tables 1 & 2

Figures 1 - 4

Table I - EMU SYSTEMS DATA

PLSS OXYGEN PRESSURE (O₂ QUANTITY)

PLSS BATTERY

◦ VOLTAGE } (ELECTRICAL ENERGY STATUS)
◦ CURRENT }

FEEDWATER PRESSURE (COOLING WATER)

PRESSURE GARMENT ASSEMBLY PRESSURE

LIQUID COOLING GARMENT

◦ H₂O INLET TEMP }
◦ H₂O DIFFERENTIAL TEMP } (HEAT LOAD INDICATION)

TABLE 2 - EVCS MODES
EVCS-2

			EVCS-1	
PRIMARY	PRIMARY	DUAL	SECONDARY	SECONDARY
	EVCS-1 & EVCS-2 HAVE NO COMM WITH EACH OTHER	EVCS-2 CAN RECEIVE FROM BOTH LM/MSFN AND EVCS-1 BUT CAN NOT TRANSMIT TO EITHER	EVCS-2 HAS NO COMM WITH MSFN	
	EVCS-1 & EVCS-2 HAVE NO COMM WITH EACH OTHER	<div> <div> FULL DUPLEX </div> <div> EVCS-1 IS RELAY </div> </div>	EVCS-2 HAS NO COMM WITH MSFN	
SECONDARY	EVCS-1 HAS NO COMM WITH MSFN	EVCS-1 HAS NO COMM WITH MSFN NOBODY CAN HEAR EVCS-2	NO COMM AT ALL	

NOTES

1. THIS CHART ASSUMES THAT THE LM COMMUNICATION SYSTEM IS IN THE CONFIGURATION THAT IS COMPATIBLE WITH THE DUAL/DUAL (NOMINAL) MODE

2. COMMENTS IN THE NON-NOMINAL CASES REFER TO DEFICIENCIES IN CAPABILITY COMPARED TO THE NOMINAL MODE.


 NOMINAL MODE

Fig. 1 - LM COMMUNICATIONS SYSTEM (INTRA-VEHICULAR CREW)

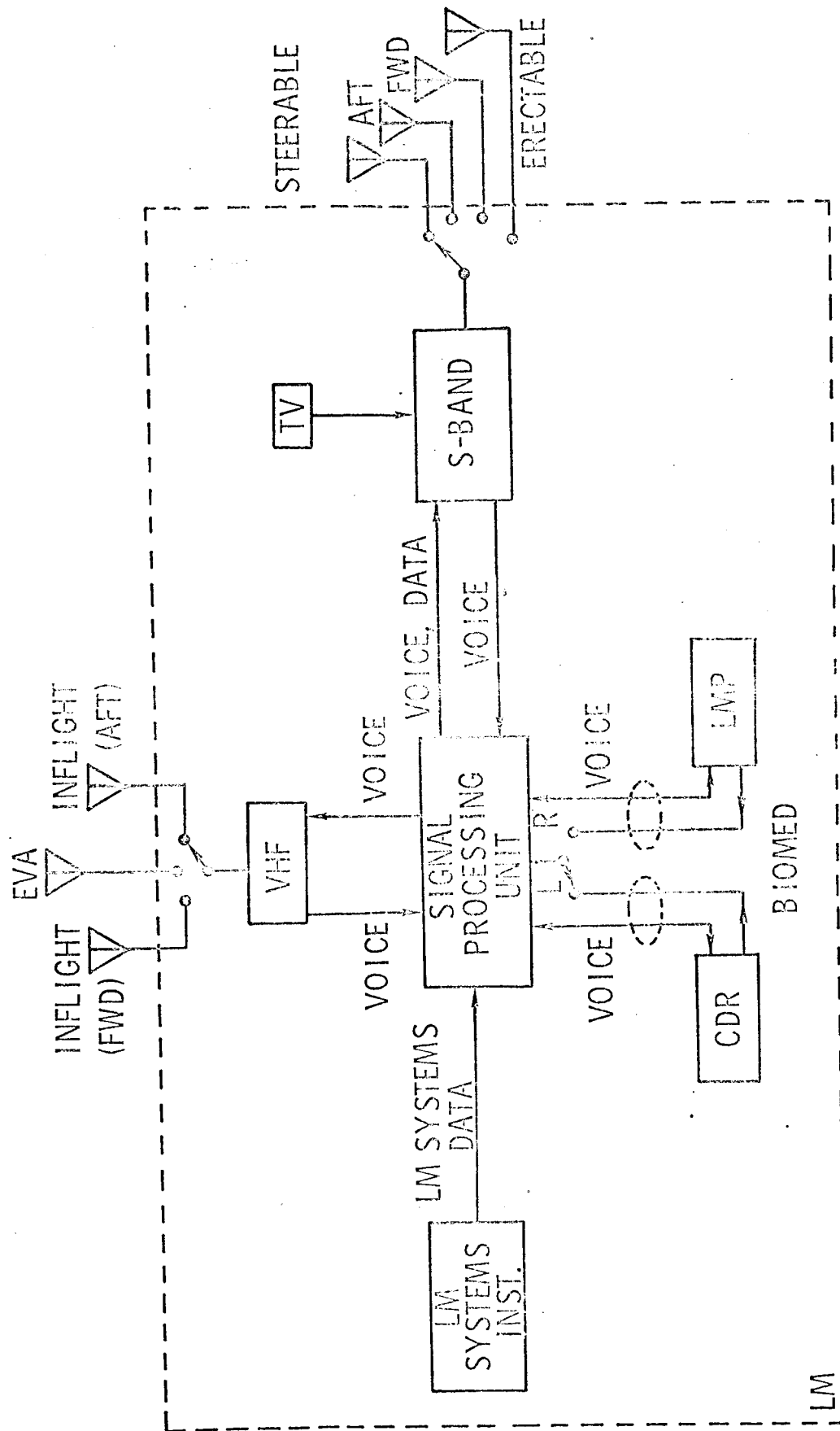


FIGURE 2 - LM VHF COMMUNICATIONS SUBSYSTEM

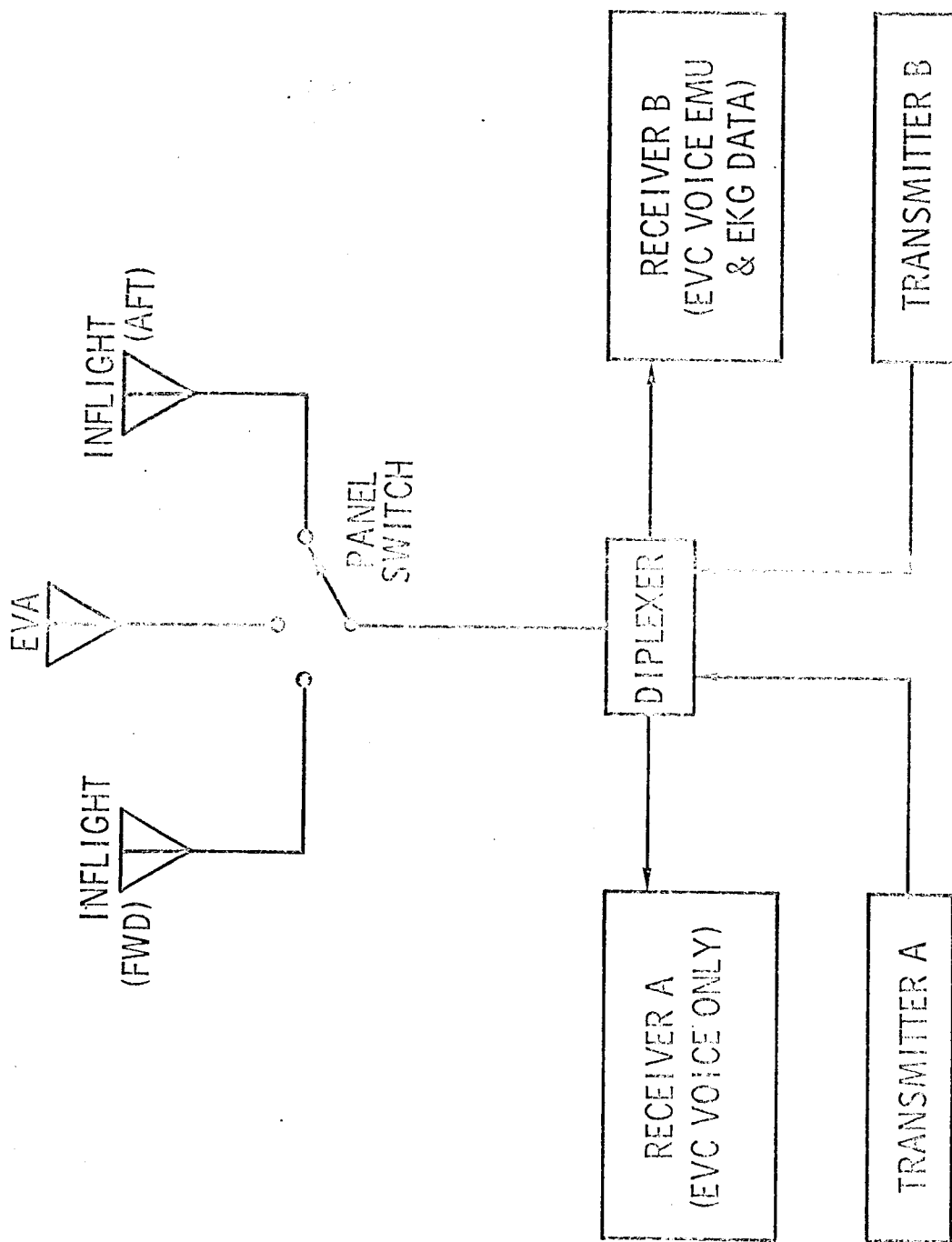
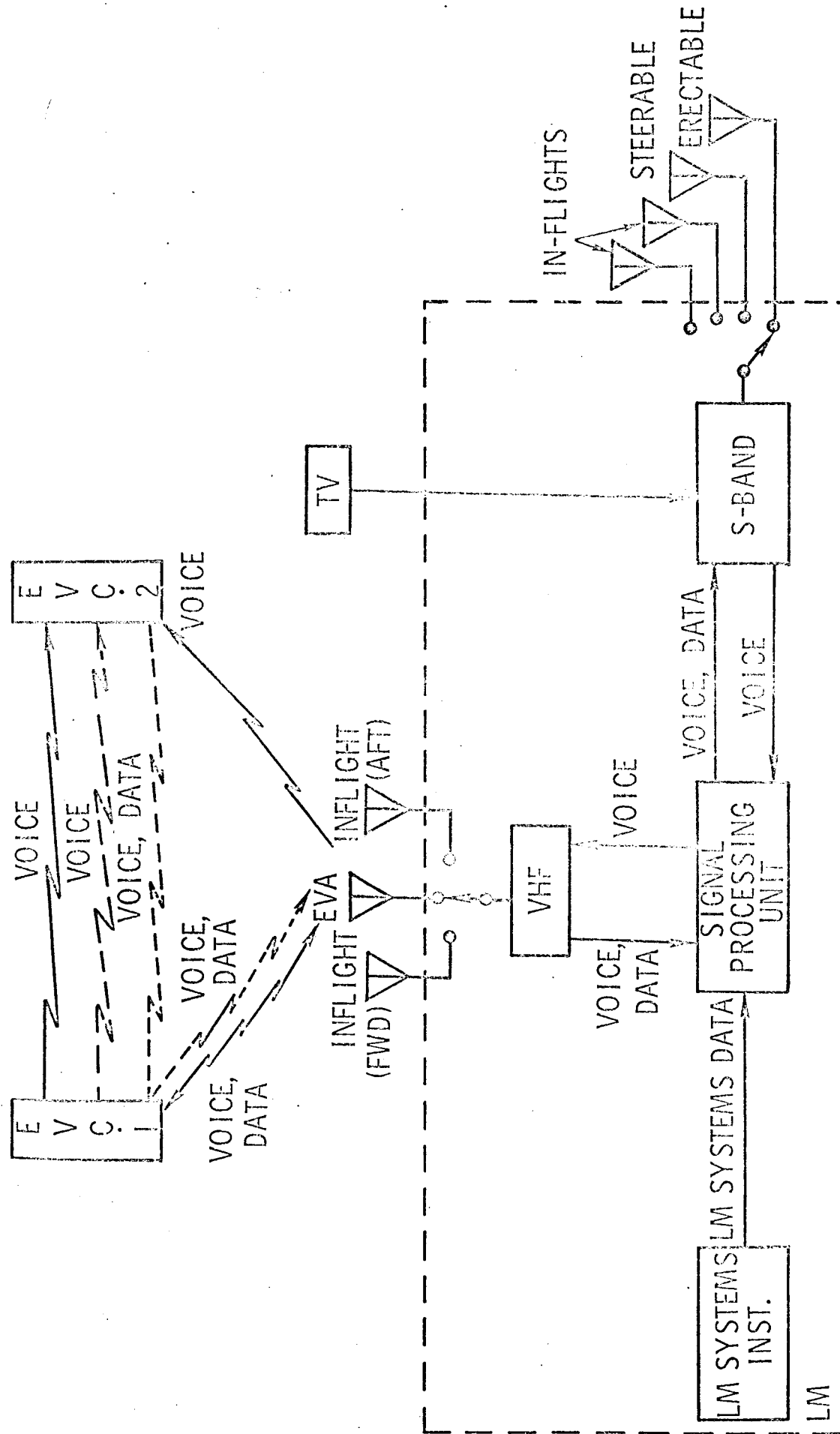


Fig. 3 - LM COMMUNICATIONS SYSTEM (EXTRAVEHICULAR CREW)



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ABSTRACT

This memorandum reviews the operational use of the Apollo communication systems during lunar surface activities. The discussion is directed primarily at the G Mission, but it should be generally applicable to later lunar landing missions. A functional description of both the Lunar Module Communications System and the Extravehicular (back-pack) Communications System is discussed in simplified form as applicable to lunar surface communications. The description is offered both to stimulate thought about future lunar landing missions and to provide a basis for discussion of possible operational problems during the first lunar landing.

Two potential problems are discussed from an operational view-point. One, a possible line-of-sight limitation on the link between the two crewmen has been the subject of recent tests at MSC which show it to be minimal. The other is a possible bandwidth/power problem in the LM communications system which arises if TV coverage of the lunar surface is desired prior to deployment of the high gain surface antenna. Possible operational solutions to this problem include postponement of the initial telecast, leaving the intravehicular crewman on LM systems during the telecast, doing without EMU and EKG data from the intravehicular crewman during the telecast, and planning for high-gain earth based antenna visibility during the telecast. Of these alternatives, planning for use of a 210 foot earth-based antenna seems to be the least undesirable solution to the potential problem presented by plans to televise man's first steps on the lunar surface.

